# SWEEP TOOL FOR R&S® NGU201, NGU401 AND NGM200

**Products:**

► R&S®NGU401

► R&S®NGU201

► R&S®NGM201

► R&S®NGM202

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# Contents

# 1 Overview

Source measure units R&S®NGU401 and R&S®NGU201 are capable of precise current measurements from sub-microampere up to ampere. This application note provides a tool which generates a voltage or current sweep using the arbitrary function of the instruments. A fast log captures voltage and current values during the sweep. Subsequently the application program determines the voltage and current value for each sweep step and plots the results in an I-V curve[1].

The tool can be utilized to characterize all kinds of two-pole devices like diodes, LEDs and solar panels.

This application note can also be used in connection with DC power supplies R&S®NGM201 and R&S®NGM202.

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[1] IV, UI, -U-I and curve tracer

# 2 Background

This tool employs several special functions of R&S® DC power supplies and source measure units. The devices supported by this application note, the special functions used and the funciton principle of the sweep tool are outlined below.

## 2.1 Source measure units R&S®NGU201 and R&S®NGU401

Power Supplies R&S®NGU201 and R&S®NGU401, further herein below called "NGU", are source measure units with standard and high-speed logging capability of voltage and current.

R&S®NGU201 can be operated as power supply (positive output current) and load (negative output current) on positive voltages. R&S®NGU401 is a four-quadrant power supply, capable of sourcing and sinking currents with positive and negative output voltages.

## 2.2 Power supplies R&S®NGM201 and R&S®NGM202

Power Supplies R&S®NGM201 and R&S®NGM202, further herein below called "NGM", are high-precision sources and sinks with standard and high-speed logging capability of voltage and current.

R&S®NGM201 provides one channel and R&S®NGM202 features two independent channels.

## 2.3 Arbitrary function

The arbitrary function in R&S® DC power supplies allows to specify variable source voltage and current setting as a function of time. [1] Value pairs of voltage and current are stored together with an associated dwell time. During the playback of the sequence, each pair is set in the output and maintained for the specified dwell time before the next pair of voltage and current values is set. The sequence starts when the respective channel is activated and, depending on the settings, is repeated cyclically or played only once. In the NGU the resolution for the dwell time is 0.1 ms, in the NGM the time resolution is 1 ms.

In manual control the arbitrary data is stored in an ASCII text file. The user interface provides an editor which allows to set up an arbitrary file on the touchscreen of the instrument. In remote control the data is uploaded from the controlling PC to the instrument via the remote-control interface, and stored into internal memory.

## 2.4 Fast logging

Fast logging records voltage and current readings versus time in fixed intervals, but without time stamps. Fast logging is always individual to each channel of the power supply. It can be configured, started and stopped in each channel independently. The data is collected in separate files.

Available sample rates for fast logging are 100, 1000, 10000, 50000, 250000 and 500000 values per second.

Fast logging data is stored in floating-point raw format. If started manually, it is stored to a USB memory stick connected to the NGM, which must support the resulting data rate. After termination of the logging, the data can be converted offline to a character-separated ASCII format. In remote control, the logging data must be collected via the remote-control interface every time the status system reports data to be available. The interface used for the remote connection must support the resulting data rate.

## 2.5  Function principle of the application program

In this application the sweep is implemented as an arbitrary sequence. From the sweep range and timing settings in the "Sweep" tab the program calculates the appropriate voltage, current and dwell values. While the sweep runs on the source measure unit or power supply, a simultaneous fast log collects the voltage and current values measured at the channel output. Due to the current limit set for a voltage sweep, or voltage limit set for a current sweep, not all configured sweep steps may actually be present in the fast log data. An offline evaluation detects the available steps of the sweep, averages measured voltage and current values over the specified aperture interval, and plots the current-voltage pairs in an I/V diagram.
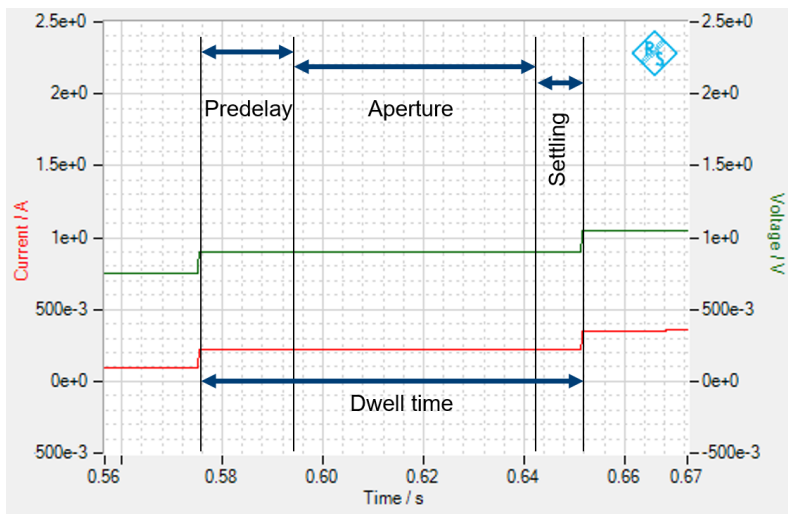
## 2.6  Timing considerations



Fig. 2-1: Timing of each sweep step

The timing for each step starts at the point where the swept quantity (voltage or current, respectively) has stabilized.

The term "predelay" specifies the time which passes from this point until the acquisition for the voltage and current measurement starts. The predelay can be used to wait until the current through the DUT (or voltage at the DUT for current sweep) has settled. Parasitic capacitances or inductances may cause transient phenomena in measured current and / or measured voltage. The influence of such transient phenomena on the accuracy of the measurement result is reduced by increasing the predelay.

The aperture is the time interval during which the voltage and current measurement is averaged for the result pair in the chart. Increasing the aperture reduces measurement noise. For very low voltage and current values it can be advantageous to average over entire periods of the AC mains, because this mostly compensates crosstalk from the mains into the measurement.

An additional settling time has to be taken into account, to allow for the transition of the swept quantity from one step to the next.

The dwell time for a single sweep step is calculated as the sum of all three intervals, rounded up to the next entire sample period of the fast logging.

# 3 Prerequisites

The following prerequisites have to be observed for a correct function of the application program.

## 3.1 Configuration of the NGU or NGM

No options are required for this application. The NGM must have firmware version 3.034 or later installed.

## 3.2 Requirements to controlling PC and software installation

The application program runs on PCs with Windows 10 operation system.

For the instrument remote control, the controlling PC must have a compatible VISA library installed. A free VISA library is available from the R&S® web site [2].

The application program requires .NET runtime 4.0 or higher. Make sure that .NET runtime 4.0 or higher is installed on the controlling PC. A compatible version 4.5 is available for download from [3]

The system partition of the hard disk must have approximately 800 Mbyte of free space to store the log data.

Copy installer "1GP129_xyz.msi" to the local hard drive of the PC and start it. Follow the instructions on the screen.

## 3.3 Remote control connection

For remote control, either a USB connection, LAN connection or GPIB connection is required between the controlling PC and the NGM or NGL, respectively. GPIB can only be used with low sample rates of the fast log. See section 4.1.1 for details.

# 4 Test setup

Observe the following hints regarding the test setup to ensure proper operation of the application program.

## 4.1 Remote control

The following sections explain how the remote control connection from the controlling PC to the instrument should be established.

### 4.1.1 Interfaces

R&S® instruments can usually be remote controlled via GPIB, LAN and USB. NGM additionally allows WLAN connection when option NGM-K102 is installed.

For the current task there are some prerequisites to observe, as the fast logging of NGU and NGM requires a certain minimum data rate, depending on the sample rate of the logging function.

The data rate of GPIB is sufficient only for the lower sample rates of the fast logging function. Therefore, GPIB is not recommended as connection to the instrument for this application.

The USB interface in the NGU and NGM supports two different USB classes. "CDC" emulates a serial interface via USB-to-serial converter and has the advantage of compatibility with older remote-control systems. The data rate of the "CDC" class is not sufficient for fast logging. Therefore "USB Class" in submenu "Device → Interfaces" has to be set to "TMC".

### 4.1.2 VISA ident strings

The NGU / NGM VISA ident string for USB has the format "USB0::0x0AAD::0x0197::3638.1234k02-123456::INSTR". The black digits and characters are invariant for all individuals of NGU and NGM, and specify interface type, manufacturer and instrument type. The violet digits are "8.4472" for NGM, and "9.3763" for NGU401 and NGU201. The blue digit specifies the instrument variant. It is "2" for NGM201and NGU201, and "3" for NGM202 and NGU401. The green digits represent the serial number of the individual instrument. The type number and serial number are shown in menu item "Device → Device Information" on the instrument.

The "IP" button opens an entry window with a template which then has to be completed with the actual IP address. The ident string for the IP LAN connection to the NGM/NGL/NGP has the format "TCPIP0::aaa.bbb.ccc.ddd::inst0::INSTR". The black part is common for most instruments and for all NGU and NGM. The green part represents the IPv4 address which can be read with NGU or NGM in menu item "LAN" of sub-menu "Device → Interfaces → Network". "aaa" can have two or three digits. All other numbers in the string can have between one and three digits.

It is also possible to use the "Find" button (see below) for discovering the instruments on USB and GPIB interfaces and obtaining their VISA ident strings. The LAN interface is not searched with the "Find" button.

## 4.2 Connecting the DUT

Keep electric connections to the DUT as short as possible. When measuring very low currents, it may be advantageous to shield the DUT and the connections. Use the separate sense lines when large currents are expected. On the NGM202 the sense lines are only available on the channel connectors on the backplane. In this case you should consider to connect the DUT on the back side of the instrument.

Hum noise may be reduced when the low terminal is grounded. The NGU has a second low force terminal and a ground terminal on the front panel, which allow a convenient connection using the jumper supplied with the NGU. On the NGM a ground clamp is provided on the backplane.

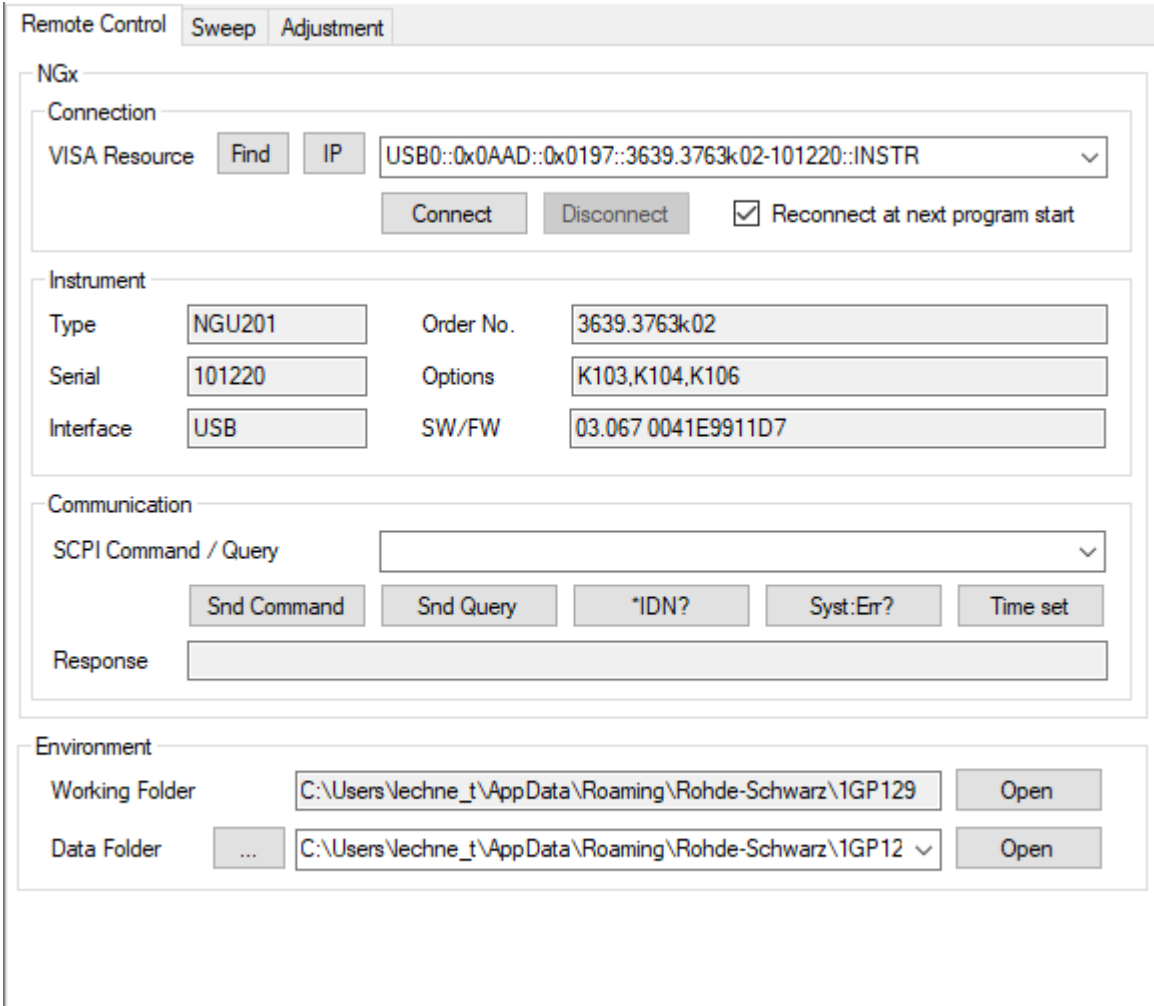# 5 User interface of the application software

## 5.1 Remote control tab



Fig. 5-1: Remote Control tab of the NGx Sweep Tool

The remote-control tab allows configuration and test of the remote-control connection to the connected DC power supply.

Enter the VISA resource string of the power supply as described in section 4.1.2 into the Visa Resource text box.

Clicking the "Find" button starts a search on the USB and GPIB interfaces and displays found NGU or NGM instruments in a new remote-control window. If multiple devices are detected, one on each interface can be selected in the comboboxes showing the resource strings, and the interface to be used can be selected with the radio buttons on top.
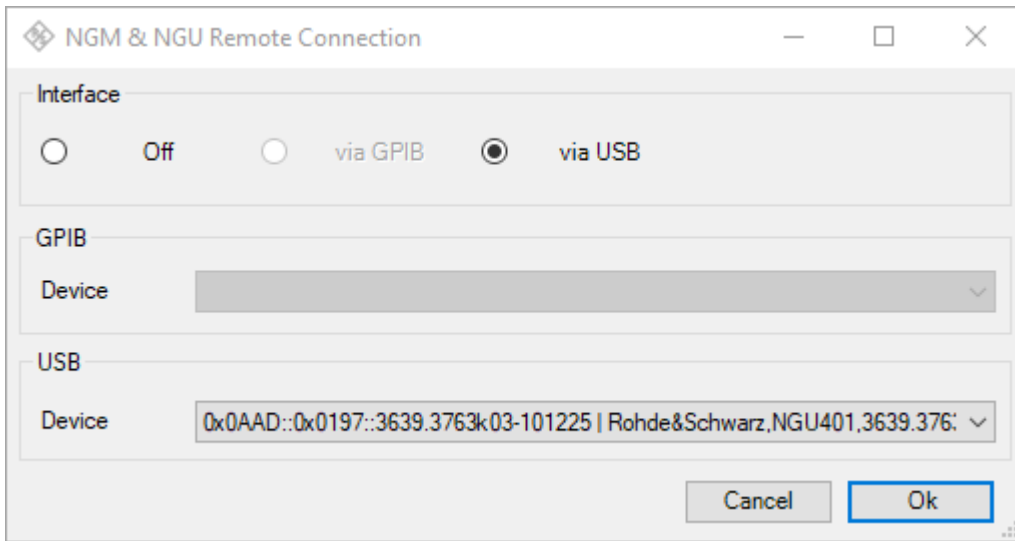
Fig. 5-2: Remote connection window

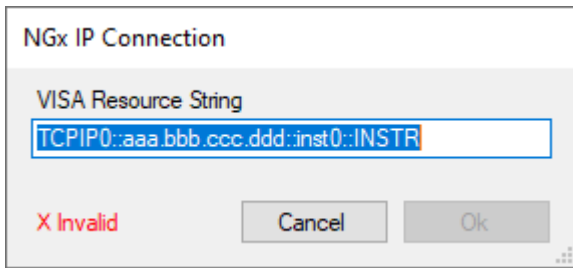Clicking the "IP" button opens an input window with a resource string template for IP connections.



Fig. 5-3: Input window for IP connections

Enter the actual IP address of the DC power supply in the places marked with "aaa.bbb.ccc.ddd".

If the resources string complies with the rules for IPv4 addresses, the window is marked with "valid" in the bottom left corner.



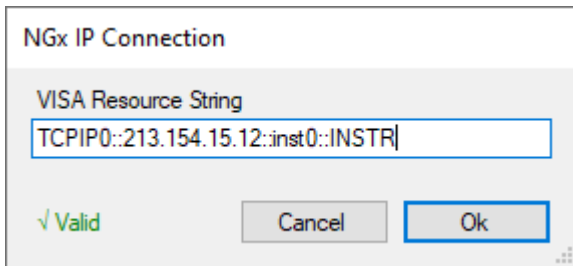Fig. 5-4: Input window for IP connections with valid entry

By clicking the "Ok" button, the resource string is entered into the VISA resource combox, and the program tries to open a connection to the specified instrument.

Any resource which has been connected successfully in the past, is stored with the settings of the user interface and appears in the resource combobox after the next start of the program.

The "Instrument" groupbox shows information about the instrument which has been successfully connected last.

The function of the remote connection can be checked with the buttons in the "Communication" groupbox. It is recommended to check the remote-control connection before using the functionality of the "Logging" tab.

"Snd Command" sends a SCPI command entered in the "SCPI Command / Query" combobox to the instrument.

"Snd Query" sends a SCPI command entered in the "SCPI Command / Query" combobox to the instrument, reads the response from the interface and displays it in the "Response" textbox.

The "SCPI Command / Query" combobox remembers the last 20 commands which have been sent successfully. To send one of these commands again, open the combobox using the small arrow on the right side, and select the desired command before clicking the "Snd Command" or "Snd Query" button, respectively.

"*IDN?" displays the identification string returned from the instrument in the response textbox.

Note: It is recommended to execute the "*IDN?" function before proceeding with the sweep setup. This ensures that the instrument can be reached by remote control. Based on the identity reported by the instrument, appropriate controls are enabled in the sweep tab, if supported by the type of the connected power supply.

"Syst:Err?" reads one entry from the error queue and displays it in the response textbox. The error queue can be regarded as a first-in-first-out buffer to which SCPI errors caused by remote commands are written by the instrument and picked up by the "SYST:ERR?" command.

"Time set" sets the real-time clock of the instrument to that of the controlling PC.

The "Working Folder" textbox displays the path of the working folder on the controlling PC used by the application program. This folder contains a file "trace.log" where error messages from the application program are written, and a file "settings.sup" memorizing the settings of the user interface at the time the application program was terminated last time. The "Open" button opens a file explorer in the application folder.

The "Data Folder" Combobox displays the path of the data folder on the controlling PC used by the application program. This folder is the target for log data from the NGM or NGL. Initially the data folder is the same as the working folder, but a different location can be selected by clicking the "…" button.

Note: The selected file location has to support the data rate and access speed required for the fast logging operation. "Jumps" in the IV diagram may be due to missing portions of fast log traces, caused by inappropriate storage media.

The "Open" button opens a file explorer in the data folder.

The combobox on bottom of the window shows the last 64 messages on the remote-control interface in use. While the combobox is closed, it shows the last message. To see the last 64 messages, click on the arrow on the right side.

## 5.2 Sweep tab



Fig. 5-5: Sweep tab of the NGx sweep tool

### 5.2.1 Sweep unit

Here you can select whether the voltage or the current is swept. Note that in both cases both quantities are measured for the curve to be displayed in the chart.

### 5.2.2 Sweep range

Enter the value range and the number of steps for the swept quantity.

### 5.2.3 Priority mode

This choice is only available on the NGU. The priority mode specifies which quantity settles faster after a sweep step. The default is voltage priority. In this mode the current can slightly exceed the specified limit for a very short amount of time, due to the settling process. If the DUT is very sensitive against overcurrent, choose current priority mode, in which the current limit is regulated faster than the voltage.

The NGM applies always voltage priority.

### 5.2.4 Current / voltage limit

After choosing the swept quantity, a limit can be set for the respective other quantity, to protect the DUT from overcurrent, overvoltage or thermal overload.

### 5.2.5 End behavior

After a single sweep, the output may be switched off, stay at the state of the last step ("Hold") or assume another defined value for the swept quantity. While the "Off" state is the default, the DUT may require one of the other options for some reason.

### 5.2.6 Timing

In this field the settling time for the sweep step, the pre-delay and the aperture can be set. For details see section 2.6. If alignment with the mains frequency is chosen, the aperture is rounded up to the next entire period of the mains.

"Time Resol." determines the sample rate of the fast log for the acquisition. It determines the available resolution for settling, pre-delay and aperture. For short settling, pre-delay and acquisition times you should choose a fine time resolution to speed up the sweep. Note, however, that a fine time resolution leads to a higher amount of voltage and current samples, which may slow down the evaluation process. The "Default" button sets the timing parameters to reasonable values enabling a relatively short sweep time. A higher measurement accuracy may be achieved on cost of sweep speed by increasing predelay and aperture.

### 5.2.7 Current measurement range

For the fast log during the sweep, auto-ranging or a fix current measurement range may be chosen.

### 5.2.8 Chart

"New" opens a new chart for each sweep. "Add" adds the trace for the next sweep to the latest available chart. A trace name can be entered in the field "Enter Trace Name" in the control groupbox. If no name is specified, the traces are named "Sweep x", with x being the continuos numbering of the traces in the chart in question.

### 5.2.9 Control

In addition to the buttons for starting and interrupting a sweep, the "Control" groupbox offers settings for an automatic start of sweeps. If the "Auto-Start" button is activated, the source measure unit applies the voltage specified in the box at its output. The output current is limited to the value set in the upper part of the tab. If a component is connected, and the current through the component surpasses the specified threshold, the next sweep is started. To avoid artefacts from contact bouncing, a delay can be inserted between the detection and the start of the sweep.

The background color of the "Auto-Start" button is green as long as the detection is active. Clicking the button a second time deactivates the detection.

## 5.3  Adjustment Tab

The adjustment function of the NGx sweep tool allows to correct offset and gain errors of voltage and current measurement. For correction of offset errors, no additional equipment is required. The correction of gain errors requires a precision voltmeter and a precision amperemeter.



Fig. 5-6: Adjustment tab of the NGx sweep tool

Current measurement offset and voltage measurement gain is adjusted with an open circuit measurement. Each adjustment is started with the respective "Adjust" button. For the voltage gain adjustment, a precision voltmeter has to be connected to the channel output. During the adjustment process the software queries the readings from the external voltmeter and compares them to the voltage readings of the source measure unit in use. This comparison results in a correction factor for each voltage readback range.

Accordingly, voltage offset and current gain correction can be determined with the channel output short-circuited. For the current gain correction, a precision amperemeter is required. The operator is prompted to enter the readings from the external amperemeter during the adjustment process.

Note that there is no gain adjustment for current ranges of 1 mA and below.

The date and time of the last adjustment is shown in the textbox in the center of each row. The comboboxes on the left side can be drilled down to view all adjustment values.

For each adjustment it is possible to select individually with the checkbox on the right side whether it should be applied to the measurements or not.
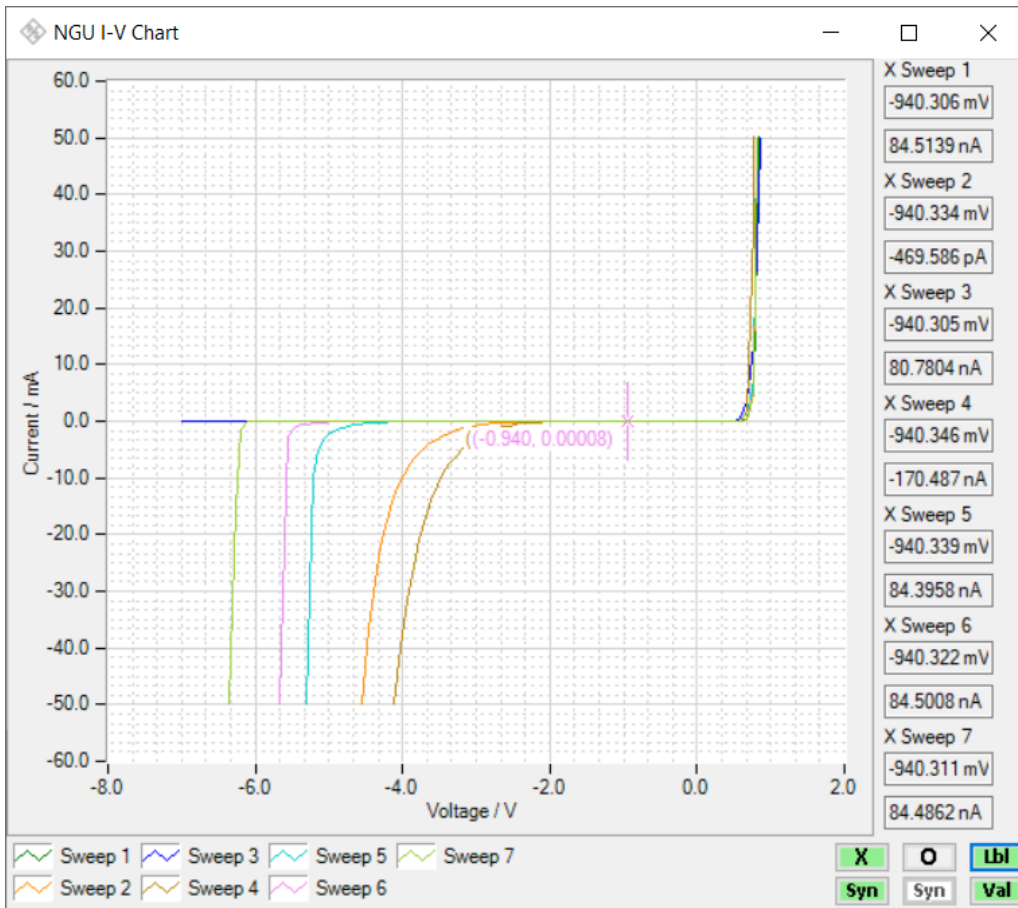
## 5.4 Chart window
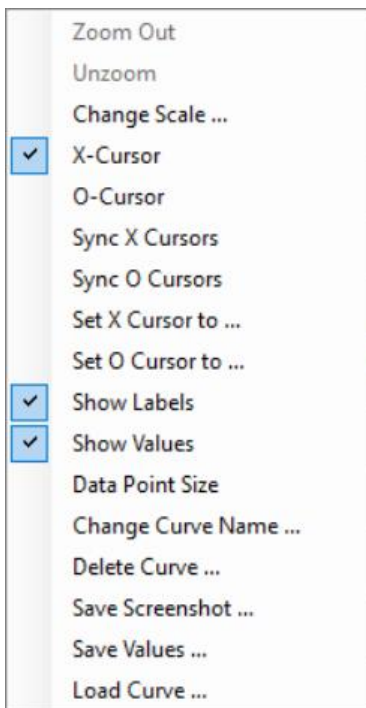


Fig. 5-7: Chart window



Fig. 5-8: Chart context menu

### 5.4.1 Chart properties

A new chart is opened if the chart mode is set to "New" or if no chart exists so far. The SI prefixes (m, μ, n) of the current axis labels are automatically aligned with the maximum and minimum values. The number of grid lines adapts to the size of the chart, and the label values at the grid lines are adjusted to round numbers. The chart supports a maximum of 10 traces with different colors and individual cursors. If more than 10 traces are shown, the colors will repeat, and additional traces will not have cursors.

### 5.4.2 Zooming and panning

Pressing the <Shift> key on the keyboard and the left mouse button, and simultaneously drawing a rectangle in the chart with the mouse causes the chart to zoom into this rectangle. Repeated zoom steps are possible. With context menu item "Zoom Out", the last zooming is undone. With "Unzoom", the chart returns to the original axis ranges.

In zoomed state, the chart can be dragged within the visible rectangle by keeping the <Ctrl> key and the left mouse button depressed, and simultaneously dragging the chart area with the mouse.

### 5.4.3 Adjusting the axis scales

With context menu item "Change scale …" a can be opened for setting the scaling of the axes.
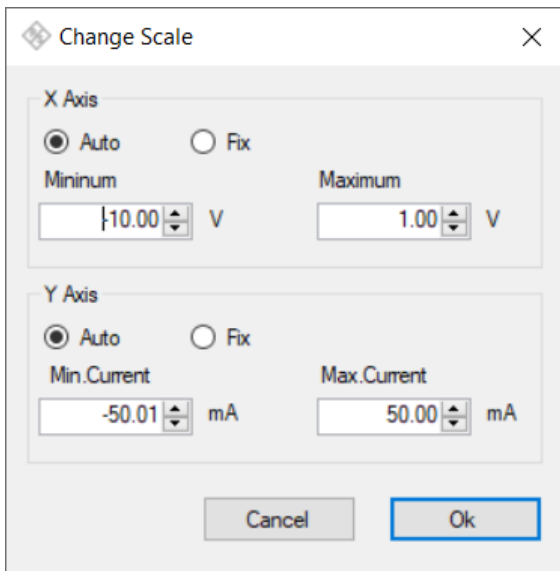


Fig. 5-9: Scaling input window

If an axis is set to "Auto", the scaling will be adjusted to show all traces completely. To set a defined scaling, change the setting to "Fix" and enter the desired minimum and maximum values. Click "Ok" to confirm the settings and close the window.

### 5.4.4 Cursors

The chart supports two cursors (X and O) per trace. Cursors can be activated and deactivated with the buttons on bottom right of the chart, or from the context menu.

There are two options for reading the x and y values of the cursors.

- Labels close to each cursor can be enabled and disables either from the context menu or using the "Lbl" button on bottom right of the chart. Labels are handy when a cursor is moved on a trace and the associated values are to be read out. However, if both cursors are active, or if the chart contains multiple traces, labels may overlap rendering some of them unreadable.

- The value strip on the right edge of the chart can show x and y values from both cursors on all traces simultaneously. It can be made visible or invisible from the context menu and by clicking the "Val" button on bottom right of the chart.

If a chart contains more than one trace, cursors on different traces can be dragged individually, or else all X cursors and all O cursors, respectively, can be synchronized across all traces. The synchronization can be enabled and disabled in the context menu or with the "Syn" buttons on bottom right of the chart.

Note that the cursors are always on measured points of the traces. Since also the X axis values are measured, the X axis values at the synchronized cursor positions may differ slightly, even if the sweep parameters of the traces are identical.

## 5.4.5   Data points

Measured values can be marked by data points, in order to distinguish them from interpolated values in the chart. The size of the data points can be set from the context menu. To hide the data points, set the size to zero.

When the Mouse cursor is hovered over a data point, the tooltip shows the x and y values of this measurement.

## 5.4.6   Changing curve names

Although a curve name can be specified for each sweep before it is started, it may be desirable to change the name of a trace in the chart, for example before taking a screenshot. This can be done with the context menu entry "Change Curve Name …".

## 5.4.7   Deleting curves

Curves can be deleted with context menu item "Delete Curve …".

## 5.4.8   Saving trace data and screenshot

Context menu item "Save Screenshot …" saves a screenshot of the chart in its current state and size to a file specified in the file selector box which opens when the menu item is clicked.

Context menu item "Save Values …" saves the trace data to an ASCII file for further processing, e.g. in a spreadsheet. Text files with ending ".txt" use a tab character for separating voltage and current values. Comma-separated character files with ending ".csv" use a comma character as value separator. The decimal separator is always a point character.

## 5.4.9   Loading trace data from a file

Select context menu item "Load Curve …" to load sweep data from a text (*.txt) file or comma-separated (*.csv) file. The file needs to be in the same format as it is created by the "Save Values" function. After choosing the source file in a file selector, curves can be selected from all available data in case the file contains multiple curves. After confirming the curve selection, the data is loaded, and the chart is updated accordingly.

# 6 Literature

[1] Rohde & Schwarz, "Emulate real-world scenarios with Rohde & Schwarz power supplies," 2021. [Online]. Available: https://www.rohde-schwarz.com/applications/emulate-real-world-scenarios-with-rohde-schwarz-power-supplies-application-card_56279-713346.html.

[2] Rohde & Schwarz, "R&S®VISA," Rohde & Schwarz GmbH & Co. KG, 11 May 2018. [Online]. Available: https://www.rohde-schwarz.com/search_63238.html?term=R%26S+VISA+software+library. [Accessed 27 June 2019].

[3] Microsoft, ".Net Framework," Microsoft, 2019. [Online]. Available: https://www.microsoft.com/en-us/search?q=.NET+Framework+4.0. [Accessed 23 October 2019].

[4] Rohde & Schwarz, "R&S®NGL200/NGM200 Power Supply Series User Manual," 13 April 2020a. [Online]. Available: https://www.rohde-schwarz.com/manual/ngl200/.

[5] Rohde & Schwarz, "R&S®NGU Source Measure Units User Manual," 16 February 2021. [Online]. Available: https://www.rohde-schwarz.com/search/search_63238.html?term=NGU+User+Manual.

# 7 Ordering Information

| Designation | Type | Order No. |
|---|---|---|
| Two-quadrant source measure unit | R&S®NGU201 | 3639.3763.02 |
| Four-quadrant source measure unit | R&S®NGU401 | 3639.3763.03 |
| Power Supply | R&S®NGM201 | 3638.4472.02 |
| Power Supply | R&S®NGM202 | 3638.4472.03 |

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